I. C. 7439

MARCH 1948

UNITED STATES
DEPARTMENT OF THE INTERIOR
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BURNING REFUSE DUMPS AT COAL MINES

BY

D. HARRINGTON AND J. H. EAST, JR.

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By D. Harrington[2] and J. H. East, Jr.[3]

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[1] The Bureau of Mines will welcome reprinting of this paper providing the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7439."

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INTRODUCTION

Burning refuse dumps are a common and by no means pleasant sight in most coal-mining districts; they have been and largely continue to be accepted as a necessary, if undesirable, adjunct to coal-mining operations. The odor, smoke, and fumes emanating from the burning dumps have caused much property damage, as well as aroused unfavorable public sentiment in the areas thus affected; and there is reason to believe that, in at least some cases, they have had an adverse effect on the health of certain communities, adjacent to mines. In some instances such communities have been owned or controlled by the mining companies and in others they are incorporated towns.

After the start of World War II, it was necessary for Great Britain to take prompt and effective measures to extinguish or at least blanket the burning refuse dumps at collieries, since the fires served as beacons for the enemy planes; the problem thus became a matter of national security rather than one of local inconvenience. If the United States should become involved in a bombing war, these dumps might become a source of national danger, hence now is a propitious time to at least make a start on available methods of solving this problem. Much progress was made in Great Britain in extinguishing the dump fires that had burned for years and in preventing newly made dumps from taking fire.

Burning refuse dumps have not been a national problem in the United States, but they are a nuisance and frequently a danger and often a fruitful cause of poor public relations on account of the odor and fumes. Many progressive coal-mining companies are taking effective and positive action in trying to extinguish old dump fires and to build new dumps so they are less likely to fire.

The purpose of this paper is to provide information about the problem as well as on ways to extinguish refuse dump fires, to describe methods of constructing dumps that probably will prevent them from firing, and to point out some of the danger that exists when dumps are improperly built and when they are on fire.

GENERAL

The problem of refuse dump fires can be divided initially into three parts:

1. The planned dump that will almost certainly fire unless corrective measures are taken from the outset.

2. The small incipient fire that will spread through the whole dump unless corrective measures are taken promptly.

3. The dump that has been burning for a considerable time.

These conditions are discussed at some length, but in every instance it hould be noted that a specific method of constructing a dump in such a maner that it will not take fire and one that has stood the test of time is ot known. Methods of making dumps that are unlikely to heat and take fire are described, though it is recognized that these methods may not be effecive in some cases.

The same statement applies to methods of extinguishing refuse dump ires; a method used to extinguish one dump fire may not be effective at nother fire. Several methods that have been used with some degree of sucess are described.

ACKNOWLEDGMENTS

Much of the information contained in this publication was obtained from eports submitted by various field engineers of the Bureau of Mines. Their ssistance is gratefully acknowledged.

KINDS OF MATERIALS LIKELY TO FIRE

Waste dumps contain refuse material that occurs in mining operations, ncluding material from the roof or floor or in driving through rock for tunnels, overcasts, etc., and it usually has less than 25 percent combustible matter, such as coal, pyrite or marcasite, "bony," and various combinations of carbonaceous material; any or all of these are likely to oxidize and under certain conditions heat and take fire. Coal, especially of the lower grades, in the virtual absence of pyrite or refuse is likely to fire spontaneously when stored in quantity and without taking certain precautions. Pyrite does not, as a rule, have much inclination to heat and take fire unless carbonaceous materials are in the same pile, but marcasite is very likely to fire under normal pile conditions.

Most refuse banks contain considerable coal, either because there is no cleaning plant and impure coal is worked, or the cleaning plant is not efficient or perhaps a certain size of coal or floor cleaning, etc., cannot be disposed of and is dumped on the refuse pile, in some cases with the intention of reclaiming it later; or considerable dirt may be on a belt or in a pit car and to save time both the coal and the dirt are sent to the refuse dump. Subsequently the coal is covered with the usual refuse, either accidentally or intentionally, and a "hot" spot may develop, especially if the coal is finely divided.

An English engineer[4/] studied refuse dump fires and concluded that the following combustible materials commonly found in the refuse dumps in Great Britain are likely to cause fires. The list is arranged in the order deemed most likely to fire:

1. Large pieces of intergrown coal and pyrite.
2. Large pieces of interstratified coal and shale.

[4/] Holmes, C. W. H., M. Met., Burning Pit Heaps: Colliery Eng., May 1939.

3. "Splint," "cannel," or dull high-ash homogeneous material.
4. Refuse from nut washers or dry cleaners when dumped separately in quantity.
5. Nutty coal of good quality. (Accidentally dumped.)
6. Slurry.

In the discussion of this list, it is pointed out that

> The oxidation of the veins of pyrite in lumps of intergrown "brasses" has a twofold effect as an accelerator of combustion, primarily because, in the presence of moisture it oxidizes at normal temperature with the evolution of heat, and secondly because this oxidation is accompanied by an expansion which splits up the pieces of intergrown material and so exposes fresh coal surfaces to warm oxidizing conditions.
>
> The indication, therefore would seem to be that coal more or less intimately associated with pyrites is more likely to cause trouble than coal by itself. When coal and shale are associated it is only comparatively rarely that one finds this association to be other than along the plane of bedding; it is seldom that a piece of intergrown coal and shale is found in which the two constituents are so closely intermeshed as is commonly the case with coal and pyrites.

Refuse dump sites that are not cleaned of trees and vegetation before dumping is started very likely will cause the dump to start to heat. The carbonaceous matter has a lower ignition temperature than the coal and thus makes it easier to start a pilot fire which may ignite the whole dump.

CAUSE OF REFUSE-DUMP FIRES

Refuse-dump fires are caused by spontaneous combustion or are ignited by outside sources, sometimes accidentally and often intentionally. The ashes remaining after a refuse dump has burned completely make a fairly good material, sometimes termed "red dog," for surfacing roads, and refuse dumps have been fired to provide this material for local roads.

Many theories have been developed to show the reason refuse dumps heat and take fire; unquestionably spontaneous combustion causes many refuse-dump fires, but no one theory seems to apply in all cases. At one time it was believed that it was necessary for iron sulfide, in the form of pyrite or marcasite, to be present with carbonaceous matter before a refuse dump would heat and take fire. This has been disproved, although there is no doubt that coal containing iron sulfides in considerable amounts will fire readily. The chief substances in the usual refuse bank that are known to be combustible are coal and iron sulfides, so that obviously one or both are responsible for the dumps heating; however, many refuse dumps contain much refuse timber, such as broken or decayed ties, waste lumber from the carpenter or car repair shops, etc., as well as decayed brattice cloth, discarded canvas tubing, etc., removed from the mine. It is also agreed generally that certain conditions must exist before a dump will heat or fire; these conditions are 1) that sufficient air must enter the refuse dump to oxidize the coal, or coal and iron sulfides, and (2) the air must be insufficient in quantity to carry away the heat generated during the oxidation, thus permitting the heat to accumulate. The reaction between coal and oxygen is considered to double for approximately every 15° F. rise in temperature, therefore, after a dump tarts to heat, the oxidation process is accelerated by the accumulated heat.

Refuse-dump fires have been caused by dumping over buried steam lines or allowing the foot of the dump to extend over the lines. The heat from the steam lines is sufficient to cause a more rapid oxidation of the coal.

SPONTANEOUS COMBUSTION OF COAL

Much has been written and many theories have been advanced in regard to the cause of spontaneous combustion of coal, but there is still a difference of opinion among scientists as to the exact way that spontaneous combustion develops, and no single theory is accepted generally by the mining industry.

The Bureau of Mines issued a publication[5] which discusses many of the theories of spontaneous combustion of coal and some of the conclusions are abstracted below:

1. All coals but anthracites undergo spontaneous heating; the liability to self heating is greatest among coals of the lower ranks.

2. Oxidation of the coal substance itself is the main cause of spontaneous combustion; some of the organic constituents may contribute more to the heating than others, but it has not been shown that any one constituent exerts a preponderant influence to the exclusion of the rest.

3. The process of spontaneous heating may be considered to take place in two stages. The first stage is operative at room temperature as soon as freshly broken coal is exposed to the air. It begins with the physical absorption of oxygen and is continued by the formation of a chemical compound of coal and oxygen, which is gradually decomposed as the temperature rises. The coal increases in weight by the amount of oxygen retained. Decomposition is not complete, however, until the temperature reaches about 445° F.

The second stage involves breaking the solid compound of coal with oxygen and formation of the final oxidation products - carbon dioxide, carbon monoxide, and water. With Appalachian coals this stage begins to be appreciable at about 85° F. and increases intensity as the temperature rises. With lower-rank coals the beginning temperature is lower. Both stages of the process go on simultaneously, therefore, from about 85° to 445° F. There is no sharp transition from one stage to the other.

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[5] Davis, J. D., and Reynolds, D. A., Spontaneous Heating of Coal: Bureau of Mines Tech. Paper 409, 1928, 73 pp.

4. Pyrite or marcasite, when finely divided, can increase the tendency of a coal to heat spontaneously. Although it has been shown that coals containing virtually no pyrite have fired spontaneously, it has also been definitely shown that fine pyrite when present in the coal is very likely to increase the rate of oxidation.

5. Opinions differ as to the effect of moisture in coal on spontaneous heating; the effect of moisture is determined largely by the condition of storage as well as the method of placing the coal in storage. Wetting down the surface of the pile changes the conditions of ventilation and may favor heating at points not reached by the water, where dangerous heating would not otherwise occur. Inherent moisture, as in subbituminous coals and lignite, has a definite effect toward increasing spontaneous combustion, especially when the coal is subject to outside weather conditions in storage.

In another Bureau of Mines publication6/ it is stated:

> An important factor in the heating process is the total surface area of the coal exposed to the air; the greater the surface the more chance of union with oxygen. For 1 ton of coal in the form of a solid cube, there is about 48 square feet of surface; as the cube is broken down to smaller sizes, say to slack coal, there may be 20,000 or 30,000 square feet. Experience indicates that good-size egg or lump bituminous coal ordinarily gives no trouble from spontaneous heating when stored, mainly because there is not enough surface area.
>
> Air moving through a pile of coal supplies oxygen for burning and also carries away heat. It may cause increased heating or increased cooling, depending upon the amount. When coal is piled by letting it drop the larger lumps fall to the outside. Such a pile creates an ideal condition for spontaneous heating. If one spot heats, it will gradually heat the whole pile. There is always the chance that some spot will receive exactly the right ventilation so that the correct amount of oxygen is brought in and yet not enough heat is carried away. There is much air movement on the outside edges yet in the center the air can hardly penetrate. There is no ventilation at some spots and much at others. Naturally, somewhere in the pile will be a spot where there is just the right ventilation to produce a "hot" spot.
>
> Foreign substances in the coal pile are always a hazard. Pieces of wood, straw, or oily rags not only affect the ventilation but frequently create pilot fires to start burning of the coal.
>
> All sources of external heat should be avoided to the extent possible.

6/ Barkley, J. F., The Storage of Coal: Bureau of Mines Inf. Circ. 7235, 1943, 14 pp.

The theory of spontaneous combustion of coal is discussed by Scott in a recent Bureau publication, particularly in regard to anthracite mine fires.[7] An extensive bibliography relative to spontaneous heating of coal is included in this publication.

PRODUCTS OF COMBUSTION

The gases evolved from a burning refuse dump include carbon dioxide, carbon monoxide, and oxides of sulfur; all of these are dangerous to breathe, and all may be found in dangerous concentrations at a dump fire under certain conditions.

The odor of a burning refuse dump is characteristic and is extremely disagreeable to most people. A free-burning dump gives off little discernible odor, but often the odor from a smoldering dump can be traced for miles. In populous communities this odor has caused considerable resentment against the owners of the dump and has caused mining companies to spend considerable sums of money in attempting to extinguish the fires. In England, largely because the odor of burning refuse dumps has become objectionable, the Ministry of Mines has attempted to have all smoldering dump fires extinguished.

The gases from a burning dump, especially dumps that have considerable iron sulfide in the material, do considerable damage to the trees and to vegetation in the area particularly on cloudy or foggy days. Instances have been reported where the fumes emanating from a burning dump on a foggy day have blighted trees and gardens as much as 3 miles distant, as well as causing the atmosphere to be almost irrespirable; also sulfur gases from burning refuse piles destroy the paint on buildings and structures in the area, and in some cases steel window casings and hinges have been virtually destroyed by the corrosive action of the sulfur gases.

The gases from a burning refuse dump are generally not particularly dangerous to persons in the vicinity of the dump, except in low places where the gas may accumulate. However, extreme care should be used in making hand excavations near the fire area. An example of the danger from carbon monoxide while making hand excavations is the following account which was published in The Iron and Coal Trades Review, March 31, 1944:

> On one occasion, a colliery representative examining a spoil bank reported there was not as much smoke visible as would come from an ordinary cigarette. Thinking it was a very simple thing, the colliery people unwisely attempted to dig out the heated area. On the first day, a hole about 6 or 7 feet deep was dug; on the second day they tried to continue, but one man collapsed in the hole. It was a damp muggy day with no wind. Subsequent tests showed that the hole contained 1 percent of carbon monoxide, and a man might easily suffer very serious effects from that quantity.

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[7] Scott, G. S., Anthracite Mine Fires - Their Behavior and Control: Bureau of Mines Bull. 455, 1944, 206 pp.

The gases from a burning refuse dump are said to have a harmful effect on the health of persons in the area, particularly persons afflicted with asthma or other respiratory ailments. This is due primarily to the oxides of sulfur in the gases.

LOCATION OF REFUSE DUMPS

The location of waste dumps, or refuse banks, is of considerable importance particularly in relatively thickly populated areas and in mountainous regions. There is always the possibility that the dumps will take fire, hence this should be given careful thought when making the selection of a site. The following suggestions are made in reference to the selection of a site for a mine refuse bank or waste dump:

(1) Dumps should not be located close to mine buildings or dwellings.

(2) Dumps should not be located near the mine-air intake. If the dump takes fire the fumes and gases would be likely to enter the mine.

(3) Dumps should not be constructed to form a dam across a valley or across a marsh. In times of heavy rains the dumps may settle or wash out.

(4) Dumps should not be extended far enough across a relatively wide valley to form a restriction in case of floods, or in case of high water if there is a stream in the valley.

(5) Dumps should not be located on steep hillsides when it is possible to avoid it. Landslides may start during wet weather; and if dwellings, buildings, tracks or other structures are below, serious damage may result.

(6) Dumps located on steep hillsides should be protected by large-capacity ditches above the dump level to catch and drain away surface water from above the dump.

(7) Dumps that will completely fill a gully or narrow valley should be constructed to provide ample passageway for run-off water during heavy rains or protracted rainy seasons. Large-diameter culverts should be placed at the lowest part of the gully or valley, sufficiently large to carry away flood water such as cloudbursts. These culverts should be kept open and free from obstructions at all times.

(8) The site for any refuse bank or waste dump should be thoroughly cleaned before any material is dumped on it. Trees, vegetation, and any carbonaceous matter should be removed and placed where it will not be covered by the dump as it advances.

(9) Refuse dumps should be completely fenced unless they are located on a side hill where it is not practical to fence the lower side because of rolling rocks and materials. All abandoned dumps should be completely fenced to prevent persons and animals from reaching them.

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(10) Refuse banks should be located so that the natural drainage from he banks will not contaminate sources of domestic water supply. The drainge water seeping through dumps frequently is acid and will render the ater supply unfit for human consumption.

(11) Waste dumps should not be located over the outcrop of coal beds r over abandoned openings to the surface; much trouble has been brought bout by the firing of coal outcrops by surface refuse dumps and, in some nstances, lives of underground workers endangered.

(12) Mine buildings, such as tipples, car-repair shops, and machine hops should not be built on refuse piles because the buildings sometimes re destroyed by fire, often the structures are subject to settlement, and n some instances employees in such buildings have been overcome by gases manating from the dump.

(13) Refuse dumps should not be so located as to cover steam lines; his should be obvious, but many refuse dump fires resulting in heavy expense ave been due to covering steam or compressed-air lines by piling mine refuse n them.

METHODS OF CONSTRUCTING REFUSE DUMPS

Too little attention has been given to the disposal of refuse from coal ines and to the possible results of placing a refuse dump in the wrong location, or constructing it in a manner that experience has shown will, in all probability, cause the dump to take fire and burn. There is no one ethod of constructing a refuse dump that will guarantee that it will never take fire unless it can be flooded. Techniques have been developed that ake the probability of heating and taking fire more remote than other ethods; but until the test of years of elapsed time has been successfully passed, no method of constructing a dump can be classed as a sure way of preventing a fire caused by heating or spontaneous combustion, since old refuse dumps have heated and taken fire after having been abandoned for any years.

The method used in constructing refuse dumps generally depends on such factors as the topography of the site, the location in reference to communities, the equipment available, and oftentimes on the personal opinion of the mine officials; very frequently little or no thought is given the matter and like Topsy the heaps "just growed."

Dumps in mountainous regions are constructed frequently by building a track along the side of a hill or mountain at a nearly level grade to a convenient site. The refuse is dumped until the available room is filled; the track is then shifted onto the dumped material and gradually extended as needed, or moved to form a fan shape. If trucks are used to haul the refuse material, the truck road is built to the desired site, the dump is constructed by dumping the trucks in the arc of a circle, and usually no attempt is made to limit the height of the dump, other than the increasing cost or some similar consideration.

Dumps are also constructed by extending a single track to the dump site, dumping on both sides of the track and raising the track when the dumped material will no longer roll away from the car.

Other methods include the use of aerial tramways to haul the refuse material in place of cars or trucks; the tram buckets or cars are dumped at selected points. Another method of constructing dumps that is not in common use in America is to dump all the material at one point thus forming a cone. This method is used sometimes when there is insufficient room for lower height dumps.

Any of the methods of constructing a dump mentioned results in the coarse material rolling to the foot of the dump, leaving a concentration of finer material in the top and center, with some coarse material mixed with the fines; naturally some fine material will be mixed with the coarse material at or slightly back from the foot of the dump. At or near the junction of the zone where most of the refuse material is fine with the zone where it is largely coarse is the most likely place for a fire to start, since there is a sufficient supply of air for oxidation of the materials but insufficient air movement to carry away all of the heat of oxidation. Very often fires are observed first near the base of the dump, but it is believed that actually the dump fires start higher up and spread against the air supply, that is, downward and outward.

A RECOMMENDED METHOD OF CONSTRUCTING A REFUSE DUMP

A relatively new way of constructing refuse dumps has been developed during the last few years in an effort to avoid having the dumps taking fire. By using this method of construction the danger of fire is minimized, though possibly not completely overcome; a definite statement that the dump will not take fire can be made only after any dump is completed and abandoned for a long period.

Low dumps that are well-compacted are unlikely to fire because air is restricted from the pile. Dumps are now being constructed in layers 10 to 15 feet thick; the piles of refuse material are leveled off with bulldozers and then compacted with heavy rollers; or, if trucks are used to haul the refuse material, the road is shifted so that in time the entire surface of the dump is compacted by the heavy vehicles. Some mining companies with plenty of available dump space allow the dump to remain idle 12 to 18 months to permit oxidation of the material before dumping the next layer, which is then compacted in the same manner as the previous layer. Using this or a similar method of constructing a refuse dump tends to prevent admission of air into the center of the pile, where it is most likely to aid in starting a fire; it also prevents undue segregation of coarse and fine materials. The edge of the dump is loose and may take fire, but the fire can be controlled or extinguished fairly readily and in some cases by merely compacting it by use of rollers or bulldozers or both.

Some of the methods of constructing refuse dumps by this method are described briefly:

Indiana Mine

The original dump at this mine was 60 feet high and was abandoned when it caught fire.

The present dump is maintained at a maximum height of 15 feet. It has been found that, when waste material is dumped and rolls to the bottom of the pile, fires occur very seldom, but when the angle is such that the dumped material piles up on the edge in place of rolling and the entire face eventually slides, then fires occur frequently.

Bulldozers are used to level the dump and compact the material, as well as to uncover any hot spot that starts smoldering.

Indiana Mine

The mine refuse is spread over a large area that is available in an adjoining strip pit. The refuse is hauled in trucks and the roads are shifted so that the heavy vehicles pack the dump surface firmly. The maximum height of the dump is 30 feet. A high crown is maintained in the center of the dump to provide drainage. The dump is 3 years old, and no fire has been experienced.

If the material at the edge of the dump appears to be loose, clay or dirt from the adjoining spoil bank is spread over the area and compacted with a bulldozer. If the edge of the dump appears to be heating, the same procedure is followed.

Ohio Mine

The refuse dump is maintained at a maximum height of 20 feet. The refuse is allowed a "cooling off" period of about 1 month, after which a layer of clay about 2 feet thick is placed on top of the dump and compacted with bulldozers; next another layer of refuse is dumped and the same procedure followed.

The refuse material contains considerable coal and is likely to fire. The new dump has been in use for 1-1/2 years and has not taken fire.

METHODS OF CONTROLLING BURNING REFUSE DUMPS

No one method of extinguishing burning-refuse-bank fires is applicable in all cases. Experience has shown that a method that seems effective at one mine or one district is not effective in another area. Fires in refuse banks may be controlled and apparently extinguished, and after a short or possibly a relatively long period the fire rekindles, and it is necessary to do the work again.

There are five principal methods of dealing with burning refuse banks, namely:

1. Digging out the fire or isolating the fire area by trenching.

2. Pumping water onto the fire area and immediate vicinity.

3. Applying a blanket or cover of incombustible material, such as limestone dust, shale dust, or slag dust over the fire area.

4. Injecting a slurry of rock dust or other incombustible material with water through drill holes into the fire area; grouting with cement is also used.

5. Use of water sprays over the fire area.

Digging Out the Fire or Isolating It by Trenching

It is seldom practical to dig out a fire in a refuse dump unless the dump is long and narrow. Most coal mines do not have equipment to do this type of work, and generally the cost is prohibitive.

A refuse dump that has fired in one portion is very likely to fire in another part, and isolating or digging out a burning section probably will need to be repeated from time to time as other portions of the dump get on fire.

An example of the tremendous task of digging out a fire in a large refuse bank is the anthracite-bank fire near Mahanoy City, Pa., where 1,685,300 cubic yards of material was moved at a cost of $532,000.

Pumping Water on the Fire Area and the Immediate Vicinity

Many refuse-bank fires have been extinguished or made dormant by flooding the fire area with water, but frequently the fire rekindles in or near the quenched area at a later time. Many people believe that application of water to a burning refuse dump is only a temporary expedient and that the dump after quenching is more likely to fire than before because the fine material of the dump has been washed away or into the cracks and crevasses and open spaces lower down, leaving passages for air to reach the original fire area or other places in the dump.

Records in many instances show that quenching the refuse dumps to extinguish a fire is of almost yearly occurrence at some mines. The water cools the temperature below the point of combustion but also assists in the oxidation of the combustible material that may be present, thus again causing the dump to heat.

In England a fire in a refuse bank was extinguished by using a slurry limestone dust and water introduced into the burning dump through 3-inch- meter steel pipes driven to an average depth of about 6 feet. The quan- y of limestone dust added to each of the holes ranged from 100 pounds to much as 20 tons in a single hole. After 3 months the fire was extinguished r a considerable area at a cost amounting to about one-tenth of that in- ved in an unsuccessful attempt to extinguish the fire with a slag-dust nket. The results obtained with the limestone slurry appear to be perma- nt insofar as extinguishing the fire is concerned, but they do not prevent other fire from occurring in another part of the dump where the conditions e likely to be similar.

Use of Water Sprays in Extinguishing Refuse-Dump Fires

Steam is accepted to be a very effective fire extinguisher, as it will support combustion as long as the temperature of decomposition of the eam is not exceeded. Obviously steam cannot be used in extinguishing mp fires; however, a finely divided water spray that is near the consist- y of mist has been used effectively for this purpose.

The application of the water sprays must cover the entire fire area and e application must be continuous; otherwise the steam from the water and material in the fire area will be likely to induce air currents that may use the fire to rekindle.

The use of a finely divided water spray to extinguish refuse-dump res overcomes some of the undesirable effects of using streams of water, nce the spray does not cut channels in the dump material that permit air reach the fire area. The water percolates through the dump material and said to promote weathering, and at the same time washes the finer parti- es down to fill the existing openings and thus exclude the air. The water rays when first applied may cause explosions owing to ignition of water s produced, and often intense steaming results for a time. Continued plication of the water sprays is likely soon to extinguish the fire or ke it dormant. This method effectively stops the odor of the burning dump d any external evidence of fire; it was used in controlling refuse-bank res in Great Britain during World War II when it was necessary to extinguish e fires because they served as markers for enemy airplanes.

EXAMPLES OF REFUSE-DUMP FIRES

Anthracite Refuse-Bank Fire

A fire in a refuse bank at St. Nicholas breaker of the Philadelphia & ading Coal & Iron Co. near Mahoney City, Pa., was discovered in November 37. The refuse dumps of St. Nicholas breaker and Maple Hill colliery met, d the fire was discovered in a low spot where the two banks come together. e refuse bank was one of the largest in the anthracite region, extending r several thousand feet in length and hundreds of feet in width, and pproximately 190 feet in depth. The fire was near the center of the bank. ain mine workings extended under the burning bank; and it was necessary to

Applying a Blanket, or Cover of Incombustible Material Such as Limestone Dust, Shale Dust or Slag Dust Over the Fire Area

Theoretically, a blanket or cover of incombustible material over the fire area should be effective, since it should cut off the supply of oxygen and the fire should be extinguished. In actual practice, covering the burning area of a dump, or covering the entire surface of the dump with incombustible material has not always been effective in extinguishing the fire.

The dumps settle, or cracks in the blanket or cover permit air to reac the fire area; the fire may become dormant and appear to be extinguished, but it will be very likely to rekindle when sufficient cracks are opened to allow the right amount of air to reach the fire area.

It is almost impossible to completely seal a dump with a blanket or cover and keep it sealed tight. The material on the slopes of the refuse bank tends to slide or wash down to the foot of the bank during periods of heavy rainfall, with consequent thinning of the cover material on the upper part of the dump; during very dry weather the surface of the cover is very likely to crack, admitting air.

Limestone dust, pulverized shale, slag dust, and washery rejects, if low enough in combustible content, are used in making the cover over dumps that are on fire or are heating. The cover material must be practically incombustible to be even partly effective.

Refuse dumps in use for dumping purposes obviously cannot be sealed tightly by a cover or blanket. However, some mines have adopted a plan of covering the refuse dumps with a blanket and trying to keep it close to or over the working area at all times.

Injecting a Slurry of Rock Dust or other Incombustible Material with Water into Fire Area

A relatively new method of controlling refuse-bank fires is to introduce a slurry into the bank through drill holes or driven pipes. The meth has been effective in preventing dump fires from spreading in some instanc but the method has not been used widely enough, or over a sufficiently lon period, to determine its efficiency in all types of refuse banks.

Commonly, vertical drill holes are drilled in the bank with churn drills and medium wet slurry of incombustible material and water added as long as the material will flow from the hole. The amount of slurry that c be placed in one hole is governed by the voids in the dump material - at o fire where churn-drill holes were used to outline the fire area, 640 bags limestone dust of 80 pounds capacity each, or 25.6 tons, were dumped into hole 165 feet deep. Excavations later showed that the slurry had penetrat radially 6 to 8 feet from the hole. At another fire, the slurry penetrat as much as 16 feet radially from the drill hole.

extinguish the bank fire, as otherwise the fire very probably would have reached the mine and caused a disastrous mine fire and one highly costly to handle.

The fire in the bank was discovered when men working underground in the area beneath the bank were affected with carbon monoxide carried down through the mine breeches or breaks to the surface through the old workings into a mechanical loading section. Pipes were driven into the bank from the surface at the fire area and gas samples taken; one sample contained approximately 14 percent carbon monoxide.

Active fire broke out on the surface of the bank, and in a very few days covered about 100 square feet. It was decided to apply a blanket of limestone dust over the active fire area to retard the fire until power shovels could be brought to the area to load out the burning material. It was decided also to use churn drills to delineate the fire area. A total of 700 tons of rock dust was used to cover an area of 7,500 square feet to a depth of from 2 to 3 feet. The procedure appeared to be ineffective as a fire-control measure.

Churn-drill holes were started and temperature readings taken at various depths as drilling progressed; it was necessary to case all holes to the full depth. Holes less than 120 feet in depth were cased with 10-inch pipe; the deeper holes required an 8-inch liner pipe as an inner casing to prevent buckling. After the drill holes had served their purpose in outlining the fire area, they were flooded with a limestone slurry containing 80 pounds of limestone dust in about 10 gallons of water; it was found later that the rock dust penetrated radially 6 to 8 feet into the surrounding material. Seventeen churn-drill holes were drilled, totaling 1,747 feet and ranging from 35 to 200 feet in depth. Rock dust was placed in 11 holes; a total of 640 bags (80 pounds per bag) was placed in one hole 165 feet deep, and in another hole 187 feet deep 621 bags of rock dust were placed. In all, 3,002 bags of limestone dust were used in the churn-drill holes.

The temperature readings in the various drill holes varied widely, ranging from the normal rock temperature of 60° to 75° F. in the areas away from the fire to as high as 700° F. in one hole. Many readings of 140° to 200° F. were recorded in the affected area.

The fire region was isolated from the remainder of the bank by trenching with draglines, leaving an island of burning material except for the main road, which was on clay. The burning material was hauled to a dump by 20 trucks of 9 cubic yards capacity and cooled with water. A total of 1,685,300 cubic yards of material was moved in isolating the fire and removing the burning material. A total of 798,900 cubic yards was loaded into trucks and hauled to the disposal area.

The burning material was dumped in individual piles until the dump area was covered; then the whole area was cooled with water from hose lines. After the piles had cooled they were leveled with a bulldozer, and another layer of hot material was added; precautions were taken to make certain that the lower layer was cooled completely before more material was added.

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A total of 28,218 man-days was worked in fighting and moving this refuse-bank fire; the total cost was $532,000.[8]

Refuse-Bank Fire in West Virginia

A mine in West Virginia produces about 1,800 tons of coal daily, and approximately 400 tons of refuse is dumped daily on the refuse bank. The bank is on fire, and it is reported that the fire has been burning over 10 years. The bank fire is controlled with limited success by placing a cover of clay over part of the bank.

The bank or dump is approximately 700 feet long and ranges from 100 feet wide at the inner end to 60 feet wide at the outer end and the height is about 40 feet at the outer end. Approximately 300 feet back from the outer end of the dump a small stream of water touches the bank and flows alongside around the end of the bank. The area affected by the fire begins at the point where the stream reaches the bank and extends out to the end of the bank. The part of the bank extending from the small stream to the inner end of the dump has not shown any indication of heating.

In applying the cover of clay, work was begun in the same direction that the refuse was dumped. Clay was applied about 2-1/2 feet in thickness and leveled with a bulldozer. As the outer edge of the bank was approached, the clay was dumped in piles and pushed over the edge and allowed to slide to the angle of repose; the side of the bank was covered to approximately the same thickness as the top. This work was not completed; the side opposite the stream of water is exposed and is now showing indications of heating. After a lapse of 4 years, the fire has never broken through the parts covered with clay, and it is possible that if the work had been completed the fires would have been extinguished.

Waste-Dump Fire in Ohio Extinguished With Water

A waste dump 100 feet high and nearly a quarter of a mile long at a coal mine in Ohio was on fire and was extinguished successfully with water.[9]

The mine operates on two shifts and produces about 3,000 tons of coal daily; the refuse amounts to approximately 320 tons; the refuse is dumped at the end of the waste pile. Washer and picking-table refuse is trucked to a long, flat, dumping ground near a creek about one-half mile from the coal-preparation plant; this latter dump was also on fire.

A 6- by 5-inch single stage pump driven by a 25-horsepower motor pumped water from a nearby creek through a 4-inch pipe line to the top of the dump. Near each hot spot or fire area a tee was placed in the water line and a

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8/ Leitch, R. D., Some Information on Extinguishing an Anthracite Refuse Bank Fire Near Mahanoy City, Pa.: Bureau of Mines Inf. Circ. 7104, 1940, 16 pp.

9/ Coal Age, Gob Fire Put Out by Nozzle System and Plenty of Water: vol. 48, No. 6, 1943, p. 78.

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-inch outlet installed; the final discharge outlet was 3/4-inch. Water ould be projected through swivel nozzles 50 feet or more, to the exact spot equired. At first holes were punched into the dump material to allow the ater to enter the pile and not run off the surface of the dump. This was ot effective, so posthole diggers were used to dig holes 5 feet deep.

One man working one shift a day cared for the pipe line, installed ozzles, and dug holes. The pump was operated 16 hours a day; any attention equired during other hours was given by night watchmen. The dumping of resh material on the waste pile was not stopped, but at the end of 6 months he fire was out. The fire in the second waste dump was extinguished in the ame manner.

It is planned to use an earth augur to make holes about 20 feet deep to et water into any remaining hot spots; it is also proposed to plow trenches ith a bulldozer over any hot spots and fill these trenches with water so he water percolating through the refuse material will continue to cool the eated mass.

The use of water to extinguish the dump fire was successful in this nstance, but other fires have not been extinguished by more or less similar ethods elsewhere. It is noteworthy that the water was applied to the fire rea 16 hours a day.

Culm-Bank Fire in Pennsylvania

A culm bank in the Northern anthracite field of Pennsylvania is on fire ollowing the removal of considerable bank material with power shovels. The ulm bank is approximately 500 feet long, 300 feet wide, and 125 feet high; it is irregular in shape and is estimated to contain 350,000 tons of mate-ial. The surface indicates that fire has burned over the entire bank at ome time in the past, but the larger part of the present bank surface is ow cool and shows no evidence of heat except at two places where slight traces of fumes and heat are evident.

Removal of some of the burned material has left a cut approximately 150 feet long by 100 feet wide. The operator of a cleaning plant for stripping coal was dumping the fines from the washed coal into the cut; the fine material was estimated to contain 50 to 60 percent coal.

It is stated that the fire within the bank has been dormant for several years and smoke and fumes had not been a nuisance during that period. The fire has become active again in the area recently disturbed by the power shovel in coal-reclaiming operations; the present active area is approximately 200 feet long and 50 feet wide and is in the shovel cut about midway to the top of the culm bank. Smoke and fumes are liberated in sufficient volumes to become a nuisance to residents in the vicinity of the bank. The burning material is chiefly "bony," with rock and a good grade of coal in the mixture.

A quantity of marketable coal had been reclaimed, but the operation had to be discontinued and the power shovel removed because of the heat of the rekindled material. The dormant or inactive burning mass became an active fire when the power shovel disturbed the surface and broke the seal, permitting air to reach the dormant fire.

Waste-dump and culm-bank fires will not burn actively if oxygen is excluded from them; however, enough heat to rekindle the fires may remain several years and cause active fires to resume as soon as air reaches them. It is obvious that dumping fines from a coal-cleaning plant that are "rich in coal" into an excavated area that is heating and where fire is known to be present is inviting a serious fire later; in fact, it is probable that the fire may not delay very long in manifesting itself.

Abandoned Waste-Dump Fire in Pennsylvania

A waste dump at a Pennsylvania coal mine was started in 1915 and abandoned in 1926; the dump heated and caught fire in 1945, after being out of use for 19 years. The dump was known to be heating in 1942, as it was observed that snow falling on the surface melted, but fumes or gases were not observed coming from the dump until the spring of 1945.

The gas from the fire has affected seriously a reforestation project at least 4 miles distant, particularly the white pine trees; red pines and others are affected also but to a lesser degree.

Local residents claim that in June 1945 a heavy fog settled over the area, and the gases from the burning waste dump became so concentrated under the fog that the atmosphere in homes nearby was almost intolerable to breathe. After the fog lifted the foliage on trees and plants in the vicinity was white to yellow and later turned brown.

Examination of the dump revealed that a quantity of recently dumped cleaning-plant refuse was burning. The odors from this fire were not particularly irritating when breathed; however, at points a large volume of fumes and gases was issuing from the abandoned refuse dump. These fumes had the unmistakable odor of sulfur dioxide and were extremely irritating to the eyes and mucous membranes of the nose and throat. There was no evidence of flame about the abandoned dump, but about midway on the slope of the dump a 5-foot band of yellowish molten material was observed; the fumes and gas appeared to be coming from this point. A grab sample of the molten material analyzed 60.3 percent free sulfur and 39.7 percent ammonium chloride. Apparently much heat was being generated by a fire near the center of the pile of refuse, and the sulfur in the marcasite or pyrite in the waste rock was being deposited by sublimation.

No effort was being made to extinguish this fire because of the experience of the company with another waste-dump fire of some years back. The company officials state that millions of gallons of water were pumped from a river onto a burning dump, but the fire continued to spread. A channel or cut was made through the dump to ground level in an effort to isolate the burning portion of the dump; some months later the part of the dump thought to be protected ignited spontaneously.

Two Explosions While Excavating Waste Dumps in Iowa

Report of Investigations 2498, issued by the Bureau of Mines in 1928 with C. A. Herbert as author, describes briefly two dust explosions under almost identical circumstances, one resulting in the burning of 6 men (three of them fatally) and the other burning 11, of whom 3 died. The published report describes the conditions as follows:

> The mines in the southeastern part of Iowa, where these two disasters occurred, are operating in a thin coal bed averaging about three feet in thickness, and are worked on the long-wall advancing system similar to that of Northern Illinois.
>
> The miners in this section are paid on a screened coal basis; in other words, receive no pay for the fine coal. As a result they use forks in loading the coal into the mine cars, and naturally a considerable quantity of coal is left along the roadways. Subsequently this fine coal, together with the roof rock that is taken down to give sufficient height on the roadways, is loaded into cars and dumped in piles on the surface. This roof rock is a black, oily shale, and the combination of fine coal and oil shale gives ample combustible material to thoroughly burn the rock as it is dumped.
>
> These rock piles, or dirt piles, as they are called, take fire spontaneously and continue to burn as long as fresh material is dumped on them.
>
> This rock, after having burned itself out, makes an excellent material for road building and also for railway track ballast. Because of this latter fact the railroads serving these mines were in each instance loading out the burned material from the side of the rock pile with a steam shovel. Having cleaned up all the loose material along the side of the pile next to the track, leaving a nearly perpendicular face, shots were placed in this straight face to bring down additional material for the shovel. In each case a slide took place following the dynamite shots. These slides brought down with them a large quantity of the recently dumped and as yet unburned fine coal from the top of the dump; this fine coal being light, naturally separated out from the heavier rock material and thus formed a dust cloud.
>
> As some of this fine coal was already burning along the outside of the pile where the air could get to it and all of it heated nearly to the ignition point, it was in just the right condition to flash into flame as soon as it was thrown into the air.

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The combined force of the slide and the rapid burning of the fine coal threw this burning dust cloud several hundred feet from the foot of the rock pile and across the railway tracks, burning those who were unfortunate enough to be in its path.

In the latter accident the steam-shovel crew saw the slide take place and shut themselves in the steam-shovel cab to escape what they thought was a dust cloud, and thus escaped injury. The others who escaped were those who were fortunate enough to have run in a direction at right angles to the path of the flame.

One of the lessons learned from the study of dust explosions in coal mines is to keep the dust thoroughly moistened at the point where ignition is likely to occur. This acts in two ways to prevent a serious inflammation of the dust: First, the water tends to compact and bind the dust and prevent dust clouds from forming, and second, if sufficient water is added, it will cool the flame of any incipient inflammation sufficiently to extinguish it.

With the above lesson in mind, it would be advisable for the railway companies engaged in loading up these old dirt dumps to thoroughly wet down the freshly dumped combustible material at the top of the dump for several days prior to its being disturbed. This could best be done by using fire hose with a pipe five or six feet long for a nozzle, which should be forced down into the material on the top of the dump to make sure that the water reaches into the heated material beneath the surface.

Refuse-Bank Fire in West Virginia

A very active fire is in progress in a refuse bank at a coal-cleaning plant in West Virginia. The fire threatened the tipple some time ago, and a 50-gallon centrifugal pump was installed to pump water from a small river onto the fire area. This procedure prevented the fire from reaching the tipple but did not extinguish the fire.

In fighting the fire, water was sprayed from a 7/8-inch hose whenever fire appeared until the area was cool enough to approach the center of the fire area. The nozzle was forced into cracks in the surface of the bank and water applied until all indications of heating had disappeared. The appearance of the bank around the tipple indicates that most of the combustible material has been burned; however, it has been necessary to apply water to the area several times since when the fire rekindled. The results indicate that applying water retards the fire but at least in many cases does not extinguish it.

Waste-Dump Fires in Great Britain

The burning waste dumps in England and Wales have long been a cause of complaint because of the gases and the odors evolved; during World War II the burning waste dumps made excellent guides for the enemy planes during the air raids and a concerted effort was made to extinguish the fires and black out the markers. Intensive studies were made to determine the most effective and at the same time the least expensive way of extinguishing the fires and preventing their recurrence. The British technical press printed considerable information on the subject, and it is said that more progress was made in controlling waste-dump fires during the war years than in any earlier period. Three hundred and twelve waste dumps were listed for investigation in 1939; most of these were on fire or showed indications of heating.

A committee of the Midland Institute of Mining Engineers studying "The Extinction and Prevention of Colliery Spoil-Heap Fires" in 1942 presented the following summary of the results of its investigations.10/

> Application of water is very effective when it is distributed through a system of sprays in such a way that it will seep into the burning heap without undue disturbance of the surface.
>
> It cannot be too strongly emphasized that spraying must be continuous, especially in the early stages until the fire is controlled, as one day's cessation may undo the good work done by a week's regular treatment.
>
> Suitable sprays not likely to choke should be used. Many types have been tried, but those with saw nicks and cone-type sprays produce the best results.
>
> A pressure of about 40 pounds per square inch is required at the sprays to produce a fine 'rain' or mist.
>
> In addition to the cooling effect, water spraying accelerates the weathering of the spoil and tends to wash fine and disintegrated material into the base of the heap, thus producing a more consolidated mass, to the exclusion of air.
>
> So long as tipping (dumping) continues, spraying should be carried on, although it need not necessarily be continuous once the heap has been cooled down. Fresh spoil, if not wetted at the time of tipping, should be well sprayed when tipping has been finished at the end of each day.
>
> Many collieries had used water to try to put out fires by (a) directing it in bulk through hose pipes, and (b) letting it run down prepared holes. Their experience was that fires, subdued for a time, frequently broke out afresh and even with increased vigor.
>
> The reason would appear to be that water, when applied in large concentrations, washes small material out from among the

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10/ Science and Art of Mining, Water-Spraying Dirt Tip Fires: vol. 3, No. 16, 1942, p. 227.

large stones leaving a porous mass through which air necessary to support combustion can readily enter.

After more than a year's experience with water spraying, it can be confidently stated that by this means, when carried out efficiently, dirt-tip fires can be kept under control.

It is obvious that, whatever method is adopted, it will be assisted by the reduction of combustible material in the spoil before tipping. In many cases the amount of coal recovered has not only prevented a nuisance, but proved a commercial success.

ACCIDENTS FROM REFUSE DUMPS

Refuse dumps are seldom considered hazardous insofar as personal injuries are concerned. The likelihood of property damage when a refuse dump is on fire is recognized and the effect of the fumes and gases from a burning refuse dump on vegetation as well as health of the people in the vicinity is well known. However, accidents to persons occur also and some of these are described briefly.

Abandoned Refuse-Dump Slide in Virginia

A slide of an abandoned refuse dump at a coal mine in Virginia demolished five houses and caused the death of seven persons, as well as covering three automobiles and trucks. The slide was caused by the refuse pile becoming saturated with water during a period of heavy rains.

The refuse material consisted of machine cuttings and rock; the dump was started in 1936 and discontinued in 1941. The dump was on the side of a mountain and partly filled a gully. The refuse material had been on fire for over 2 years but was not on fire at the time of the accident.

Heavy rains resulted in the seepage of water into the refuse dump and the surface drainage of the area above was directed into the gully occupied by the dump. The water coursed through the bottom of the dump, and when the whole mass became sufficiently wet, the weight forced the bottom of the pile to be projected with considerable force, covering the entire valley to a depth of 20 feet and about 400 feet wide, partly blocking a river, and covering five dwellings. The people in the dwellings did not have a chance to escape, and seven persons were killed; several other persons were injured, but not fatally.

Child Killed in Burning Refuse Bank

A British technical magazine (Colliery Guardian, July 15, 1938) reports that a child 22 months old received fatal burns while climbing up the side of a burning waste dump.

The child was picking flowers at the base of the dump; the mother of the child was in the garden, and the father was watching the child. The ather went indoors for a few moments and on looking through the window saw hat the child had climbed about three quarters of the way up the slope of he bank to a point where it was burning and had sunk into the fire area up o her thighs. There was no smoke from the burning part of the dump unless here was rain.

This accident occurred in England but the same type of accident can asily happen at many of the hundreds of burning refuse piles at American ines.

Burning Refuse Dump Sets Fire to Coal Bed at a Virginia Mine

A burning refuse dump at a mine in Virginia set fire to a coal bed and aused a small explosion which resulted in the death of two men who were inestigating the occurrence.

The accident occurred in an abandoned area of the mine; two coal beds ad been worked, and an opening to the surface had been driven from the lower ed. Later a second opening was made to the surface from the upper coal bed nd waste material dumped into the valley. The waste material gradually ccumulated and finally completely covered the lower opening. The waste ump caught fire and was not extinguished; apparently the danger of the fire ntering the lower mine opening was overlooked.

A motor crew took a trip of waste material to the dump and noticed hat a disturbance had occurred at the mouth of a room and that a stopping ad been blown out, apparently by forces from the inside of the room. The ine foreman and the motor boss went into the mine to investigate without ny respiratory protection whatever, but carrying flame safety lamps. These en did not return, and some hours later a rescue party entered the mine and ound one man dead and the second in such serious condition that he died a hort time later.

The mine fan had been shut down for 2 to 3 hours the previous day, and vidently an explosion occurred shortly after the fan was started. It is elieved that the burning dump had set fire to the coal bed in the abandoned pening and that as long as the fan was operating the gaseous products of ombustion were burned or diluted and carried away, but when the fan stopped the gases accumulated and the explosion resulted.

It is common practice at coal mines to locate the refuse bank where it is most convenient to have it without regard to the outcrops of the coal eds. This practice has resulted in many mine fires that have been difficult nd costly to extinguish.

Man Cremated by Burning Refuse Bank

A British magazine (The Science and Art of Mining, July 27, 1940) eports that a surface worker employed in covering a burning refuse bank with artly incombustible material broke through the surface crust and was engulfed y the red-hot material and cremated.

A burning refuse bank had been covered with a fine washery reject containing about 70 percent of incombustible material to a depth of 18 inches about a year before the accident. Conditions improved, but the fire continued to burn underneath the cover. A second layer of the same material was being added, and it was planned to make the second layer 30 inches thick, a total of 4 feet of cover.

The work was begun on one side of the dump, hauling the cover material to the dump in cars. Three men dumped a car and it left the track; in rerailing the car, one man stood on the original layer of cover material and in lifting the car, the downward pressure of his feet caused him to break through the thin, hard crust into a crevasse of red-hot material below. The mass closed in and he was engulfed. Efery effort was made to recover the body, but it was never found and was doubtless cremated.

This accident illustrates the danger on the surface of a refuse bank on fire, when the fire is not in evidence on the surface. The surface should be thoroughly cooled with water before men are permitted in the fire area.

Explosion at a Refuse Bank in Alabama

An explosion of coal dust at a refuse dump in Alabama caused the death of two men while they were excavating burned refuse material from the side of the bank with a dragline. The excavated material was used for surfacing roads.

The county officials had been using the burned dump material for building roads and had left a shovel cut about 50 feet high, with the side sloping at about 85°. The mining company continued to dump refuse daily. The top of the bank directly above the shovel cut contained a considerable quantity of unburned refuse.

A coal-stripping operator needed material to surface some roads and moved a dragline with a 70-foot boom to a section of the dump that had not been disturbed by the county operations, about 75 feet from the shovel cut. The dragline started to work, and during the lunch period about 30 tons of unburned refuse material slid into the shovel cut where the county had last removed the burned material. The bank was extremely hot, and smoke rose from various parts of the dump.

The sliding unburned refuse material raised a cloud of dust, and the fire in the bank ignited it, causing a violent explosion. The two men at the dragline, 75 feet from the origin of the explosion, were badly burned and died later. The explosion covered an arc of about 90° and extended for approximately 400 feet from the bank.

This accident illustrates the danger of excavating in a burning refuse dump, particularly when unburned refuse is present that may slide and raise a dust cloud. Coal dust is explosive when mixed in a dense cloud in air, and, if a source of ignition is present, a violent explosion is likely to occur.

Extreme precautions should be taken to prevent formation of a dust loud when material is moved from a burning refuse dump. Numerous exploions of this type have occurred and generally result in serious injuries nd fatalaties.

SUMMARY AND CONCLUSION

Refuse dumps at coal mines are likely to heat and take fire, causing bjectionable smoke, fumes, and odors and doing considerable damage to trees, egetation, and gardens in the vicinity, as well as offering a menace to ife and limb of persons or animals that inadvertently or otherwise walk on r fall into them. At one time, burning refuse dumps were accepted as ecessary in coal mining, but experience has demonstrated that the fires can e controlled and dumps can be built that are unlikely to heat and take ire; moreover, public opinion and public policy are veering toward preenting this particular type of nuisance.

Refuse dumps contain rock, coal, coal and pyrite, or marcasite, generlly some extraneous carbonaceous matter, such as wood, and vegetation. The resence of wood or vegetable matter, with their lower ignition temperatures, ncreases the likelihood of fire.

Heating and taking fire of refuse dumps are generally considered to be ue to the lack of enough circulation of air to carry away the heat of oxiation of the dump materials at some point inside the dump.

Refuse dumps are likely to heat and fire if they are so constructed hat the coarse material rolls to the foot of the dump and the fine material egregates largely near the top and center of the pile.

Oxidation of the finely divided coal is the main cause of spontaneous ombustion; some of the organic constituents may contribute more to the heatng than others, but it has not been shown that any one constituent exerts a reponderant influence to the exclusion of the rest.

All coals, especially in finely divided condition, undergo spontaneous eating to some extent; the likelihood of self-heating is greatest among oals of lower rank, particularly subbituminous or lignitic coals. Anthraite under certain conditions of size and storage has been known to fire pontaneously, though formerly it was believed that anthracite was not subect to self-heating.

The smaller sizes of coal are more subject to spontaneous combustion han the larger sizes, due to the increased surface area exposed to the air, ence to oxidation. For example, 1 ton of coal in the form of a solid cube as about 48 square feet of surface area; however, 1 ton of slack coal has etween 20,000 and 30,000 square feet (and possibly more) of surface area.

Carbon dioxide, carbon monoxide, and oxides of sulfur are the common roducts of combustion from burning refuse dumps. All these gases are dangerous to breathe in certain concentrations, and under some conditions concentrations may be encountered in low places or in pits dug in the surface of dumps.

A recommended method of constructing a refuse pile is to dump the refuse material in layers 15 to 20 feet in thickness and level the top of the pile. The surface should be compacted by rolling or other means and the material allowed to oxidize and cool for a few weeks or months before the next layer of refuse is placed. When it is feasible to do so, a cover of incombustible material, such as clay, should be spread over each layer of refuse after it had been compacted; there is less likelihood of heating and firing when this method of construction is used than when the refuse is thrown into high piles and not compacted.

There are several methods of attempted control or extinguishment of burning refuse dumps including:

1. Digging out the fire area, or isolating it by trenching.

2. Pumping water onto the fire region and immediate vicinity.

3. Applying a blanket or cover of incombustible material over the fire territory and vicinity.

4. Injecting a slurry of incombustible material and water into the fire area.

5. Use of water sprays.

Digging out the fire is impractical in many instances because of the size of the dump, the lack of equipment suitable for the work, and the cost of the operation; moreover, under some conditions it is a hazardous job.

Pumping water onto the fire may extinguish it, but also this procedure may cause rekindling of the fire later as the air will be likely to enter the dump through the channels cut by the water.

A blanket of incombustible material over a burning dump might be effective in extinguishing a fire if the blanket is sufficiently heavy, completely covers the affected region, and is maintained airtight; this is very difficult to attain. Placing a blanket of incombustible material over a fire area frequently brings the fire under control, but it is likely not to extinguish it.

Injecting a slurry of incombustible material and water into the fire area has been used to advantage in some cases to control refuse-dump fires. It is of particular value as a means of isolating fire and preventing it from spreading until it can be extinguished or loaded out. Pulverized limestone, such as is used for rock-dusting coal mines, provides a particularly effective type of slurry.

The use of water sprays applied continuously to a fire area has proved successful in extinguishing many refuse-dump fires. It is an effective way of controlling the fire, and the dump is less likely to heat and rekindle than when streams of water are used.

Relatively recently methods have been devised using dry ice in extinguishing spontaneous fires in stored-coal piles; there is good reason to elieve that this method can be applied with success in extinguishing refuse-pile fires.

A method of constructing refuse dumps that is guaranteed not to heat nd take fire has not been devised so far as known. Dumps constructed as recommended in this paper are less likely to take fire than those constructed without taking precautionary measures; but proof of the effectiveness takes ears to determine, since old dumps have heated and fired for no apparent reason after having been abandoned for a decade or more. However, the recommended method is believed to be effective.

Many accidents have occurred as a result of refuse dumps, particularly hen they are on fire. The crust that forms over the surface of a fire area frequently resembles a solid formation, while in reality it has little trength and will not support the weight of a person. Serious accidents and fatalities have been caused by this condition; often the ashes over a supposedly burned-out portion of a mine-refuse pile give the appearance of being harmless, but they cover burning embers sometimes red-hot and to a depth of several feet.

The prevention of refuse dump fires is important in all coal-mining areas in improving public relations, in addition to the prevention of actual danger and possibly considerable property damage from the burning dumps. The public relations angle is far more important in this matter than has been realized, not only in connection with the attitude of employees of mining companies but also that of coal consumers and the general public. This is recognized by some progressive coal-mining companies, with the result that considerable sums are spent in attempting to prevent refuse dumps from firing. The cost of building a dump that is not likely to fire may be higher than other types of dumps, but the over-all cost of a dump that heats and takes fire and then must be extinguished or otherwise controlled probably will far exceed the additional cost of a properly constructed dump due to planning ahead and taking advantage of available precautions.

One very important consideration that is relatively new makes elimination of burning refuse piles at mines of much more importance in the future than in the past; many thinking people fear that this country may become involved in a bombing war, and it may be of vital importance to prevent these refuse fires at mines from being beacon lights for enemy bombers and bombing. Here it may be reminded that an ounce of prevention is worth a pound of cure.

Serious consideration should be given (especially where surface subsidence is a problem) to devising methods and procedures for utilizing waste dumps (in whole or in part) for back-filling worked out regions in coal mines. This has been done to some extent, but the method might help to solve several problems and in at least some cases might result as a revenue producer instead of adding to mine cost.

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